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# METEOROLOGICAL VARIABLES ASSOCIATED WITH POPULATION DENSITY OF CULTURABLE ATMOSPHERIC BACTERIA AT A SUMMER SITE IN THE MID-WILLAMETTE RIVER VALLEY, OREGON


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**14. ABSTRACT**
Six of 20 environmental parameters were statistically selected as significant conservative, dependent parameters in statistical tests that would determine the parameter's ability to account for the variability of the dependant variable, culturable atmospheric bacteria (CAB), in 1$^{st}$, 2$^{nd}$, or 3$^{rd}$ degree linear models. The six parameters were (1) wind direction 10 m above ground level (AGL), (2) air temperature difference between 2.3 and 6.3 mm AGL, (3) wind speed @ 1.7 m AGL, (4) air temperature, (5) relative humidity @ 2.3 m AGL, and (6) time of day. Using the foregoing parameters, the models went from relatively poor (i.e., Adj. $R^2$=0.37) to moderately good (i.e., Adj. $R^2$=0.59). With these parameters, high CAB values were associated with morning convective air due to solar heating of the earth. This resulted in high air temperatures and consequent low relative humidity air masses that traversed the agriculturally, very active, Willamette River Valley, OR, with winds from the ENE. Thus, the atmospheric bacterial sources in these winds were probably from plant/soil surfaces and farming operations.

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## 1. INTRODUCTION

The effects of environmental conditions on survival of airborne bacteria have largely been determined in laboratory studies (e.g., Ehrilich, *et al.*, 1970a,b; Dimmick, 1960; Babich and Stotzky, 1974; Lighthart, 1973; Tong, and Lighthart, 1998). Relatively little research has been done to evaluate the *insitu* environmental conditions associated with their atmospheric abundance and dynamics. In the distant past Miquel and Bnoist (1890) outside Paris, Vladavets and Mats (1958) near Moscow and more recently, Lighthart and Shaffer (1995) in Oregon's Willamette River Valley tried to associate atmospheric bacterial abundance to meteorological conditions. The importance of understanding the consequences of the environmental conditions is indicated most dramatically in the use of dynamic mathematical models to simulate rather well known atmospheric bacterial population dynamics (Lighthart and Kirilenko, 1998; Lighthart and Shaffer, 1995). Further, the annual and diurnal concentration of atmospheric bacteria has been hypothesized to be associated with the annual and daily solar cycles (Lighthart, 1999).

For additional information, recent books and mini-review articles describing the distribution and ecology of total and culturable atmospheric bacteria are: Dimmick and Akers, 1969; Lighthart and Mohr, 1994; Cox and Wathes, 1995; Mohr, 1997; and Lighthart, 1997, 2000.

The purpose of this study was to confirm and extend our understanding of the atmospheric bacterial population dynamics in the Willamette River Valley, Oregon from our previous work (i.e., Lighthart and Shaffer, 1995).

## 2. METHODS

To determine if there could be a statistically significant relationship of 20 measurable environmental parameters (Table 1) and the culturable atmospheric bacteria (CAB) concentration 1.3 m above ground level (AGL) found at a location in the mid-Willamette River Valley during the summer of 1996, the following sampling, bacteriological, and statistical methods were used.

### 2.1 Sampling.

Meteorological and bacteriological sample measurements were obtained from instruments mounted on a 10 m meteorological tower located 100 x tower height meters from any physical obstructions during the summer of 1996. The tower was

Table 1. Complete List of Continuous or Derived Categorical Meterological and Bacteriological Parameters Showing those used in the Final Analysis (*)

| Meteorological parameters | | Bacteriological parameters (CFU/m$^3$) | |
|---|---|---|---|
| **Continuous** | **Catagorical** | **S-T-A sampler** | **Andersen sampler @2.3 m AGL** |
| Inversion height estimation (m) | Julian dates of observations | Atmosphere | Total bacteria ≥0.65 to 1.1 μm |
| Leaf wettness (%) | JD204-207 | Total bacteria 0.3 m AGL* | Total bacteria 1.1 to 2.1 μm |
| Rain (mm) | JD 221-222 | Total bacteria 6.3 m AGL | Total bacteria 2.1 to 3.3 μm |
| Relative humidity (%) | JD 232-235 | Total bacterial flux* | Total bacteria 3.3 to 4.5 μm |
| 0.3 m AGL | JD246-249 | Pigmented bacteria 0.3 m AG | Total bacteria 4.5 to 7.0 μm |
| 2.3 m AGL* | Leaf wettness | Pigmented bacteria 6.3 m AG | Total bacteria > 7.0 μm |
| Sensible heat flux | 0 | Soil | Total bacteria ≥ 0.65 to > 7.0 μm |
| Soil Moisture (bar) | >0% | Total bacteria | |
| Solar radiation (kW/m$^2$) | Weather | Pigmented bacterria | |
| Temperature (ºC) | Clear | Grasseed windrow | |
| 0.3 m AGL | Cloudy | Total bacteria | |
| 2.3 m AGL* | Time of day | Pigmented bacterria | |
| 6.3 m AGL | 0000 to ≤0600 h | Grass stubble | |
| Ground 0 m AGL | 0600 to ≤1200 h | Total bacteria | |
| Soil -0.1 m AGL | 1200 to ≤1800 h | Pigmented bacterria | |
| Time of day* | 1800 to ≤2400 h | Grass straw | |
| Wind speed (m/s)* | Day or night | Total bacteria | |
| 1.7 m AGL* | Solar radiation = 0 kW/m^2 | Pigmented bacterria | |
| 10 m AGL | Solar radiation > 0 kW/m^2 | | |
| Wind direction @ 10 AGL (º)* | Wind direction | | |
| Wind speed@direction 3.5 m AGL (º) | 10º to ≤150º | | |
| U-direction | 150º to ≤230º | | |
| V-direction | 230º to ≤10º | | |
| W-direction | Temperature difference (2.3-6.3 m)* | | |
| Wind speed@direction Standard Deviation | Small (0) | | |
| U-direction | Moderate (>0≤1.5 | | |
| V-direction | Large (>1.5) | | |
| W-direction | Wind speed | | |
| | Calm (0 m/s) | | |
| | Moderate (>0≤1.5 m/s) | | |
| | Fast (>1.5 m/s) | | |
| | Air temperature | | |
| | Cool (≤18º) | | |
| | Moderate (>18<27º) | | |
| | Warm (≥27º) | | |
| | Relative humidity | | |
| | High ( ≥65º) | | |
| | Low (<65º) | | |

modified (see Fig. 1 in Lighthart and Shaffer, 1994) with 3, hand-crankup platforms at 0 (i.e., low), 2 (i.e., mid), or 6 (i.e., high) m AGL plus the displacement distance and aerodynamic roughness length (Stull, 1988) of 0.33 m. Meteorological measurement instruments were placed on the tower as follows: temperature (Campbell Scientific, Logan, UT) at low and high levels, hygrometer (Campbell Scientific, Logan, UT) at the mid level, pyranometer (LI-COR, Inc., Lincoln, NE) with southern exposure at the low level for cleaning purposes, cup anemometer and wind direction (MetOne, Inc., Grants Pass, OR) at 10 m AGL. If the air mass being observed was warmer at 2.3 m than 6.3 m, the air mass was considered to be ascending or unstable, and descending or stable under the reverse conditions. Three-axis sonic anemometer/thermometer (Applied Technologies, Inc., Boulder, CO) was located in the mid range tower height facing the prevailing wind and operated at 0.1 s data sampling rate that was averaged over 10 or 20 min. for datalogger storage. Ground temperature and RH at 0 m AGL and soil temperature at –0.1 m AGL measurements were also recorded.

2.2 Bacteriological Sampling.

Two-slit impact samplers (S-T-A Biological Samplers; New Burnswick Scientific Co., Edison, NJ) were located both at the low and high meteorological tower platforms. Samplers were run at 28.3 l/min for the Andersen samplers and 55 l/min for the slit samplers for 20–50 depending on the expected airborne bacterial concentration. S-T-A Biological sampler data at the high level and Andersen sampler data were not reported.

The CAB collected in the S-T-A samplers were grown on Luria Bertani agar (LB; Difco Laboratories, Detroit, MI), amended with 200 µg ml-1 cycloheximide (Sigma Chemical, C., St. Louis, MO) to inhibit fungal growth. The agar plates were incubated for 7 D at 25°C and colonies counted thereafter in 2 min segments. Finally, 10 min mean counts of the colonies on the replicate plates were recorded.

2.3 Statistical Analysis.

To assure a statistically conservative analysis, any CAB observation outliers (i.e., those observations not fitting the straight line lognormal CAB distribution) and their associated continuous, environmental, independent parameter observations were eliminated. Any of the 20 independent parameter observation Mahalanobis Distance outliers were removed from consideration in the analysis using JMP v4.0.2 (SAS Institute. Cary, NC). In addition any of the independent parameters missing > 30% of its observations were also removed from the data analyses. After removal of these data, a Stepwise Regression was performed to determine which of the remaining independent parameters contributed significantly (i.e., where Mallows criterion, $C_p$, approaches $p$, the number of parameters in the model) to the model. This elimination process left 6 independent parameters with up to 4149 measurements each. The remaining parameter are: (1) air temperature 2.3 m AGL, (2) relative humidity 5 m AGL, (3) wind speed 1.7 m AGL, (4) wind direction 10 m AGL, (5) temperature difference 2.3 m–6.3 m AGL, and (6) time of day. Subsequently, 3 6-way factorial analyses were

generated with either main effects only, or 2nd, or 3rd degree interaction linear models. Finally, an analysis of variance (AVOVA) was performed to determine if the generated models were statistically significant representatives of the CAB data.

Where categorical variables were used they were defined by logical delineation of distribution histographs as follows: day or night as solar radiation > or 0 kW/m$^2$; weather as clear or cloudy; time of day as 0000 to <0600 h, 0600 to <1200 h, 1200 to <1800 h, 1800 to <2400 h; and wind direction 10° to <150°, 150° to <230°, and 230° to <10°.

## 3. RESULTS

On 4 of the 14 observation days, 31 outlying CAB observations (i.e., 0.74%) and their associated independent parameter observations were removed from the analysis as they did not fit the straight line quantile plot of the lognormal distribution of the rest of the CAB observations, i.e., any mean colony forming unit (CFU) counts >218 were outside the 95% confidence distribution of the data. They formed another distinct angle and line at the upper end of the distribution. Almost all of the 31 CAB outliers occurred when large agricultural machines were operating next to the observation tower. (One could conclude that agricultural machines could contribute to false background readings.) Of the 4180 observation sets, 205 (4.9%) had Mahalanobis Distances > 5.1 and were also removed as outliers from the analyses. Next, 9 of the 20 independent parameters had ≥ 30% of their observations missing and 7 exceeded acceptable Mallow's criterian statistics as determined by the Stepwise Regression process; all were deleted from the analysis (Table 1). Finally, 6 parameters were left each with 3,944 data items: (1) wind direction at 10 m, (2) air temperature difference between 2.3 and 6.3 m (±ΔT), (3) wind speed at 1.7 m, (4) time of day, (5) air temperature at 2.3 m, and (6) air relative humidity at 2.3 m.

ANOVA for 1st (main effects), 2nd, and 3rd degree interaction models, all using the 6 parameters listed above, were all highly significant (i.e., F-value <0.0001; Table 1) with all 6 parameters included as highly significant in each model (Table 2).

The 3 6-way factorial analyses for the linear models had a range of effects from a poor main effects model fit (adj. $R^2$=0.37) to a moderate fit (adj. $R^2$=0.59) of the 3rd degree model to the CAB observations. In the 1st degree model, 92.6% of the model fit was accounted for by 2 parameters, wind direction and the temperature difference between 2.3 and 6.3 m (=86.9+5.7). Wind speed, temperature at 2.3 m, RH and time of day accounted for the remaining 7.4% of CAB variation in the data model (Table 3). In the 2nd degree interaction model, 83.8% of the variation in the model was accounted for by the relative humidity and temperature at 2.3 m while the temperature at 2.3 m and ±ΔT interaction accounted for a further 12.9% or almost all of the model fit, i.e., 83.8+12.9%=96.7% (Table 4). Finally, the 3rd degree interaction model, 67.2% of the variation in the model was accounted for by the relative humidity and temperature at

Table 2. Observation Dates and Times at the Willamette River Valley Station in 1996

| | Time of day | |
|---|---|---|
| Date | Start | End |
| 22-Jul | 1005 | 2000 |
| 23-24 Jul | 1830 | 1400 |
| 25-Jul | 0130 | 1200 |
| 6-7 Aug | 1740 | 0400 |
| 8-Aug | 0130 | 1220 |
| 9-Aug | 1010 | 2000 |
| 19-Aug | 1010 | 2000 |
| 20-21 Aug | 1740 | 0400 |
| 22-Aug | 0130 | 1220 |
| 2-Sep | 1015 | 2000 |
| 3-4 Sep | 1740 | 0400 |
| 5-Sep | 0500 | 2150 |

Table 3. Parameter Frequency Distribution Moments (Less All Outliers) that Account for 100% of the Variation in the CAB Main 1st Degree Effects Model

| Parameter | Parameter range (peak) | % of $R^2$ (=0.37) | CAB N | Mean | Standard deviation | Standard error of the mean | Upper 95% confidence limit | Lower 95% confidence limit | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|
| Wind direction @ 10 m AGL (º) | 10-150 (64)* | 86.9 | 151 | 125.6 | 64.8 | 5.3 | 136.0 | 115.1 | 256.0 | 0.0 |
| | 151-230 (171) | | 50 | 95.8 | 55.8 | 7.9 | 111.6 | 79.9 | 252.5 | 8.8 |
| | 231-10 (307) | | 223 | 56.0 | 39.5 | 2.6 | 61.2 | 50.8 | 234.8 | 0.0 |
| Temperature difference @ 2.3 -6.3 m A | Small (< 0)** | 5.7 | 107 | 49.7 | 30.6 | 3.0 | 55.6 | 43.8 | 196.0 | 0.0 |
| | Moderate (≥ 0 ≤ 1.5) | | 83 | 78.4 | 60.7 | 6.7 | 91.6 | 65.1 | 256.0 | 0.0 |
| | Large (> 1.5) | | 234 | 104.4 | 63.7 | 4.2 | 112.6 | 96.2 | 256.0 | 0.0 |
| Wind speed @ 0.3 m AGL (m/s) | Calm (≤ 0.447)** | 2.3 | 62 | 61.5 | 49.1 | 6.2 | 74.0 | 49.1 | 252.5 | 0.0 |
| | Light (>0447 ≤ 2.25) | | 86 | 83.6 | 60.6 | 6.5 | 96.6 | 70.6 | 238.4 | 0.0 |
| | Mod/Fast (> 2.25) | | 276 | 91.5 | 62.2 | 3.7 | 98.8 | 84.1 | 256.0 | 0.0 |
| Time of day (6h intervals) | 0000-0600 h | 1.9 | 101 | 47.1 | 30.7 | 3.1 | 53.2 | 41.1 | 194.2 | 0.0 |
| | 0601-1200 h | | 88 | 118.0 | 59.2 | 6.3 | 130.6 | 105.5 | 252.5 | 26.5 |
| | 1201-1800 h | | 130 | 104.5 | 65.6 | 5.7 | 115.9 | 93.1 | 256.0 | 0.0 |
| | 1801-2400 h | | 105 | 71.6 | 54.3 | 5.3 | 82.1 | 61.1 | 256.0 | 0.0 |
| Air temperature @ 2.3 m AGL (ºC) | Cool (18)** | 1.0 | 165 | 69.9 | 47.2 | 3.7 | 77.2 | 62.7 | 252.5 | 0.0 |
| | Moderate (≥ 18 < 27) | | 181 | 74.5 | 54.0 | 4.0 | 82.4 | 66.6 | 238.4 | 0.0 |
| | Warm (≥ 27) | | 78 | 143.9 | 67.5 | 7.6 | 159.1 | 128.7 | 256.0 | 28.3 |
| Relative humidity @ 2.3 m AGL (%) | High (≥65%)** | 2.1 | 336 | 72.3 | 51.5 | 2.8 | 77.8 | 66.7 | 252.5 | 0.0 |
| | Low (<65%) | | 88 | 136.0 | 67.6 | 7.2 | 150.3 | 121.6 | 256.0 | 26.5 |

* peak value; ** limits

Table 4. Parameter Frequency Distribution Moments (Less All Outliers) that Account for 99.3% of the Variation in the CAB 2nd Degree Interaction Effects Model

| Parameters | | % of $R^2$ (=0.49) | CAB: N | CAB: Mean | CAB: Standard deviation | CAB: Standard error of the mean | CAB: Upper 95% confidence limit | CAB: Lower 95% confidence limit | CAB: Maximum | CAB: Minimum |
|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature @ 2.3 m AGL (ºC)** | **Relative humidity @ 2.3 m AGL (%)** | 83.8 | | | | | | | | |
| Cool* | Low** | | No data | No data | No data | No data | No data | No data | No data | No data |
| Cool | High** | | 165 | 69.9 | 47.2 | 3.7 | 77.2 | 62.7 | 252.5 | 0.0 |
| Moderate* | Low | | 22 | 75.3 | 50.3 | 10.7 | 97.6 | 53.0 | 233.1 | 26.5 |
| Moderate | High | | 159 | 74.4 | 54.6 | 4.3 | 83.0 | 65.8 | 238.4 | 0.0 |
| Warm* | Low | | 66 | 156.2 | 60.4 | 7.4 | 171.0 | 141.3 | 256.0 | 44.1 |
| Warm | High | | 12 | 76.4 | 67.3 | 19.4 | 119.1 | 33.6 | 249.0 | 28.3 |
| **Temperature difference @ 2.3 -6.3 m AGL (ºC)** | **Temperature @ 2.3 m AGL (ºC)** | 12.9 | | | | | | | | |
| Very unstable*** | Cool | | 24 | 116.3 | 53.9 | 11.0 | 139.1 | 93.6 | 220.7 | 40.6 |
| Very unstable | Moderate | | 139 | 79.8 | 51.5 | 4.4 | 88.5 | 71.2 | 238.4 | 0.0 |
| Very unstable | Warm | | 71 | 148.3 | 64.0 | 7.6 | 163.5 | 133.2 | 256.0 | 35.3 |
| Unstable*** | Cool | | 49 | 81.4 | 54.6 | 7.8 | 97.1 | 65.7 | 252.5 | 15.9 |
| Unstable | Moderate | | 28 | 72.2 | 66.4 | 12.5 | 97.9 | 46.4 | 211.9 | 0.0 |
| Unstable | Warm | | 6 | 82.7 | 87.2 | 35.6 | 174.2 | -8.8 | 256.0 | 28.3 |
| Stable*** | Cool | | 92 | 51.7 | 27.1 | 2.8 | 57.3 | 46.1 | 132.4 | 0.0 |
| Stable | Moderate | | 14 | 26.2 | 14.1 | 3.8 | 34.4 | 18.1 | 53.0 | 1.8 |
| Stable | Warm | | 1 | 196.0 | . | . | . | . | 196.0 | 196.0 |
| **Wind direction (º)** | **Time of day (6 h intervals)** | 2.6 | | | | | | | | |
| 10 to 150º | 0000-0600 | | 15 | 67.0 | 51.0 | 13.2 | 95.2 | 38.7 | 194.2 | 0.0 |
| 10 to 150º | 0601-1200 | | 52 | 120.9 | 61.5 | 8.5 | 138.0 | 103.8 | 249 | 26.5 |
| 10 to 150º | 1201-1800 | | 75 | 133.0 | 63.1 | 7.3 | 147.6 | 118.5 | 256 | 35.3 |
| 10 to 150º | 1801-2400 | | 9 | 187.9 | 42.2 | 14.1 | 220.4 | 155.5 | 256 | 105.9 |
| 151-230º | 0000-0600 | | 12 | 60.8 | 23.5 | 6.8 | 75.7 | 45.8 | 104.2 | 24.7 |
| 151-230º | 0601-1200 | | 24 | 115.2 | 62.2 | 12.7 | 141.5 | 88.9 | 252.5 | 35.3 |
| 151-230º | 1201-1800 | | 14 | 92.5 | 50.6 | 13.5 | 121.7 | 63.3 | 164.2 | 8.8 |
| 151-230º | 1801-2400 | | No data | No data | No data | No data | No data | No data | No data | No data |
| 231-10º | 0000-0600 | | 74 | 40.9 | 23.5 | 2.7 | 46.3 | 35.4 | 125.4 | 0.0 |
| 231-10º | 0601-1200 | | 12 | 111.1 | 45.0 | 13.0 | 139.7 | 82.5 | 215.4 | 65.3 |
| 231-10º | 1201-1800 | | 41 | 56.5 | 41.4 | 6.5 | 69.5 | 43.4 | 158.9 | 0.0 |
| 231-10º | 1801-2400 | | 96 | 60.7 | 41.0 | 4.2 | 69.0 | 52.4 | 234.8 | 0.0 |

* Cool (<18º), Moderate (≥18<27º), Warm (≥27º), ** High (>40%), Low (≤40%); *** Very unstable (1.5), Unstable (≥0<1.5), Decending (<0);

2.3 m, and wind direction interaction. An additional variation of 14.7% more was accounted for by the temperature at 2.3 m, and ±ΔT and wind speed at 1.7 m interaction giving a total accounting of 81.9% of model fit of adj. $R^2$ of 0.59 (Table 5). In conclusion, 5 of the 6 parameters accounted for most of the variation of the CAB data with the difference in temperature the only parameter found in all 3 models while the other 4 were found in only 2 of the models.

It must be emphasized, that albeit the fit of the 1st degree model accounted for only 37 % of variation in the CAB observations all 6 of the parameters were highly significant contributors to the model (Table 3). Further, 92.6% of the adjusted $R^2$ fit-value was due to 3 parameters, wind direction, ±ΔT, and wind speed. Wind direction alone accounted for 86.9% of the fit-value (Table 3). The parameters in the 1st degree model were significant and were the only ones used in the 2nd and 3rd models, consequently they must also be significant in the higher degree models.

## 4. DISCUSSION

This report is a general description of the parameter qualities as they appear to be related to the quantity of CAB in the summer time at the observation location in the agriculturally very active Willamette River Valley, in western Oregon. These features are shown in Figures 1, 2, and 3, and Table 5. The figures show that generally higher concentrations of CAB are associated with warm, dry, unstable air (i.e., (+)ΔT), winds coming from the ENE down the Valley. This scenario comes about when solar radiation occurs especially in the morning hours. In the late afternoon and evening, on shore winds became moderate (< 15 m/s) out of the WNW and abated about 2000 h. The lower concentrations of CAB are generally associated with cool, moist, stable (i.e., (-) ΔT) WNW winds coming across the Douglas fir covered Pacific Coast Mountain Range from the Pacific Ocean some 80 km to the west. The lower concentrations occur during nighttime and pre-dawn hours.

Figures 2, 3, 4, and 5 shows that there are distinct meteorological conditions associated with the natural prevalence of culturable airborne bacteria at the observation location during the summer: (1) daytime moderate ascending winds from the ENE traversing bacterial sources, plant and dry soil surfaces of the Willamette River Valley, and (2) nighttime light descending winds from the WNW over and through gaps in the Douglas fir forests of the Pacific Coast Mountain Range from the Pacific Ocean. The ocean air could be the source of the relatively clean air (Schroeder, Fosberg, Cramer and O'Dell, 1967; Olsen and Tuft, 1970; Neff and King, 1987; Lighthart and Shaffer, 1995).

There are several features of the CAB data that need to be addressed if progress is to be made in understanding the dynamics of natural populations of airborne bacteria in the atmosphere. The first is the liberation mechanism. How do bacteria get from a static position on a source surface to the airborne situation? Is it an air motion or wind mechanism (e.g., Aylor, 1975)? Is it an electrostatic repulsion mechanism when

Table 5. Parameter Frequency Distribution Moments (Less All Outliers) that Account for 81.9% of the Variation in the CAB 3rd Degree Interaction Effects Model

| | | | % of $R^2$ | CAB | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | N | Mean | Standard deviation | Standard error of the mean | Upper 95% confidence limit | Lower 95% confidence limit | Maximum | Minimum |
| **Wind direction (°)** | **Temperature 2.3 m AGL (°C)** | **Relative humidity 2.3 m AGL (%)** | 67.2 | | | | | | | | |
| 10-150 | Cool** | High*** | | 26 | 98.1 | 64.2 | 12.6 | 124.1 | 72.2 | 241.9 | 0.0 |
| 10-150 | Moderate ** | High | | 56 | 108.8 | 53.4 | 7.1 | 123.1 | 94.5 | 238.4 | 26.5 |
| 10-150 | Warm ** | High | | 3 | 159.5 | 99.1 | 57.2 | 405.7 | -86.7 | 249.0 | 53.0 |
| 10-150 | Cool | Low*** | | No data | No data | No data | No data | No data | No data | No data | No data |
| 10-150 | Moderate | Low | | 10 | 101.3 | 60.0 | 19.0 | 144.3 | 58.4 | 233.1 | 35.3 |
| 10-150 | Warm | Low | | 56 | 157.5 | 62.7 | 8.4 | 174.3 | 140.7 | 256.0 | 44.1 |
| 151-230 | Cool | High | | 29 | 94.3 | 58.4 | 10.9 | 116.5 | 72.1 | 252.5 | 24.7 |
| 151-230 | Moderate | High | | 20 | 97.6 | 54.6 | 12.2 | 123.1 | 72.1 | 219.0 | 8.8 |
| 151-230 | Warm | High | | No data | No data | No data | No data | No data | No data | No data | No data |
| 151-230 | Cool | Low | | No data | No data | No data | No data | No data | No data | No data | No data |
| 151-230 | Moderate | Low | | 1 | 102.4 | . | . | . | . | 102.4 | 102.4 |
| 151-230 | Warm | Low | | No data | No data | No data | No data | No data | No data | No data | No data |
| 231-10 | Cool | High | | 110 | 56.8 | 31.8 | 3.0 | 62.8 | 50.8 | 215.4 | 0.0 |
| 231-10 | Moderate | High | | 83 | 45.6 | 36.9 | 4.1 | 53.6 | 37.5 | 197.8 | 0.0 |
| 231-10 | Warm | High | | 9 | 48.7 | 17.5 | 5.8 | 62.1 | 35.2 | 79.5 | 28.3 |
| 231-10 | Cool | Low | | No data | No data | No data | No data | No data | No data | No data | No data |
| 231-10 | Moderate | Low | | 11 | 49.1 | 24.0 | 7.2 | 65.2 | 33.0 | 97.1 | 26.5 |
| 231-10 | Warm | Low | | 10 | 148.7 | 45.8 | 14.8 | 182.2 | 115.2 | 234.8 | 88.3 |
| **Wind speed @ 10 m AGL (m/s)** | **Temperature @ 2.3 m AGL (°C)** | **Temperature difference @ 2.3-6.3 m AGL (°)** | 14.7 | | | | | | | | |
| Calm* | Cool | Very unstable**** | | 1 | 123.6 | . | . | . | . | 123.6 | 123.6 |
| Calm | Cool | Unstable*** | | 7 | 153.6 | 75.9 | 28.7 | 223.8 | 83.4 | 252.5 | 75.9 |
| Calm | Cool | Stable*** | | 45 | 52.0 | 27.4 | 4.1 | 60.2 | 43.7 | 125.4 | 0.0 |
| Calm | Moderate | Very unstable | | 1 | 77.7 | . | . | . | . | 77.7 | 77.7 |
| Calm | Moderate | Unstable | | 1 | 28.3 | . | . | . | . | 28.3 | 28.3 |
| Calm | Moderate | Stable | | 7 | 24.5 | 13.2 | 5.0 | 36.6 | 12.3 | 38.8 | 1.8 |
| Calm | Warm | Very unstable | | No data | No data | No data | No data | No data | No data | No data | No data |
| Calm | Warm | Unstable | | No data | No data | No data | No data | No data | No data | No data | No data |
| Calm | Warm | Stable | | No data | No data | No data | No data | No data | No data | No data | No data |
| Light* | Cool | Very unstable | | 6 | 159.2 | 51.8 | 21.2 | 213.6 | 104.8 | 219.0 | 105.9 |
| Light | Cool | Unstable | | 12 | 94.6 | 58.3 | 16.8 | 131.6 | 57.6 | 217.2 | 17.7 |
| Light | Cool | Stable | | 36 | 52.2 | 30.7 | 5.1 | 62.6 | 41.8 | 132.4 | 0.0 |
| Light | Moderate | Very unstable | | 18 | 114.9 | 60.2 | 14.2 | 144.8 | 84.9 | 238.4 | 26.5 |
| Light | Moderate | Unstable | | 9 | 88.7 | 74.7 | 24.9 | 146.1 | 31.2 | 197.8 | 0 |
| Light | Moderate | Stable | | 4 | 30.5 | 18.1 | 9.1 | 59.3 | 1.7 | 53 | 8.8 |
| Light | Warm | Very unstable | | 1 | 229.5 | . | . | . | . | 229.5 | 229.5 |
| Light | Warm | Unstable | | No data | No data | No data | No data | No data | No data | No data | No data |
| Light | Warm | Stable | | No data | No data | No data | No data | No data | No data | No data | No data |
| Moderate to fast* | Cool | Very unstable | | 17 | 100.8 | 48.8 | 11.8 | 125.9 | 75.7 | 220.7 | 40.6 |
| Moderate to fast | Cool | Unstable | | 30 | 59.3 | 24.9 | 4.6 | 68.6 | 50.0 | 150.1 | 15.9 |
| Moderate to fast | Cool | Stable | | 11 | 48.9 | 9.9 | 3.0 | 55.6 | 42.3 | 61.8 | 35.3 |
| Moderate to fast | Moderate | Very unstable | | 120 | 74.6 | 48.5 | 4.4 | 83.4 | 65.8 | 238.4 | 0 |
| Moderate to fast | Moderate | Unstable | | 18 | 66.3 | 63.8 | 15.0 | 98.1 | 34.6 | 211.9 | 0 |
| Moderate to fast | Moderate | Stable | | 3 | 24.7 | 15.1 | 8.7 | 62.2 | -12.8 | 38.8 | 8.8 |
| Moderate to fast | Warm | Very unstable | | 70 | 147.2 | 63.7 | 7.6 | 162.4 | 132.0 | 256 | 35.3 |
| Moderate to fast | Warm | Unstable | | 6 | 82.7 | 87.2 | 35.6 | 174.2 | -8.8 | 256 | 28.3 |
| Moderate to fast | Warm | Stable | | 1 | 196.0 | . | . | . | . | 196.0 | 196.0 |

* Calm (≤0.447 m/s), Light (≥0.447 ≤2.25 m/s), Moderate to fast (> 2.25 m/s); **Cool (<18°), Moderate (>18<27°), Warm (≥27°); *** High (>40), Low (≤40%)
**** Very unstable (1.5), Unstable (≥0<1.5), Stable (<0).

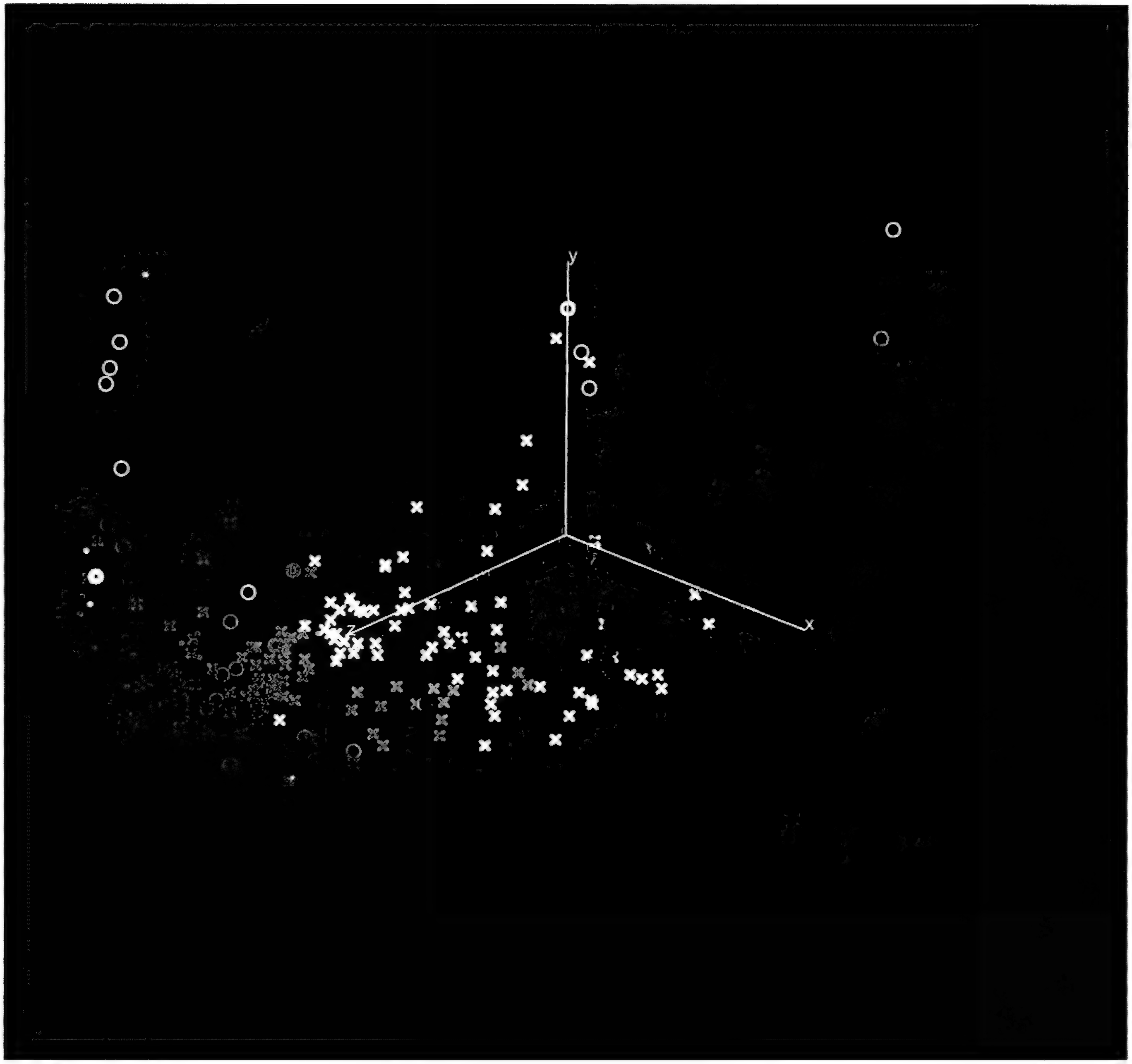


Fig. 1. 3D-Plot of Temperature (X-Axis) and Relative Humidity (Z-Axis) 2.3 m AGL and Mean CAB 0.3 m AGL (Y-Axis). Colored symbols for 2.3 & 6.3 m temperature difference (magenta, (+$\Lambda$T) or ascending; blue green, (-$\Lambda$T) or descending; white, neutral); symbols for prevailing wind directions ((x) or WNW (230 to 10° with mean 307°); (0) or ENE (10 to 150° with mean 64°), ( □ ) 150 to 230°) during the summer of 1996 at the Willamette River Valley observation station.

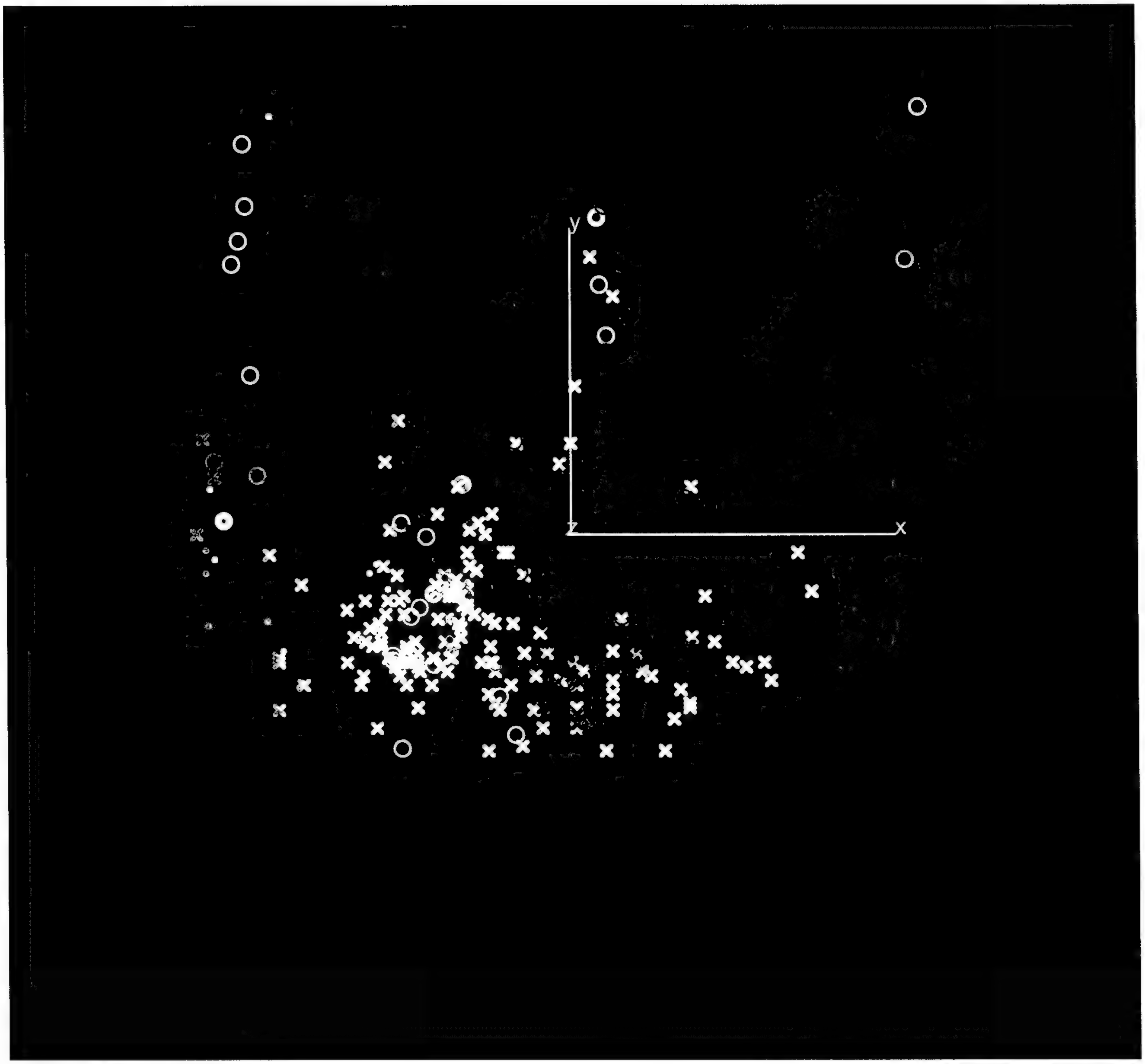


Fig. 2. Graph of Temperature (X-Axis) 2.3 m AGL and Mean CAB 0.3 m AGL (Y-Axis). Colored symbols for 2.3 & 6.3 m temperature difference (magenta, (+$\Lambda$T) or unstable air; blue green, (-$\Lambda$T) or stable air; white, (0) or neutral air); symbols for prevailing wind directions ((x) or WNW (230 to 10° with mean 307°); (0) or ENE (10 to 150° with mean 64°), ( ... ) 150 to 230°) during the summer of 1996 at the Willamette River Valley observation station.

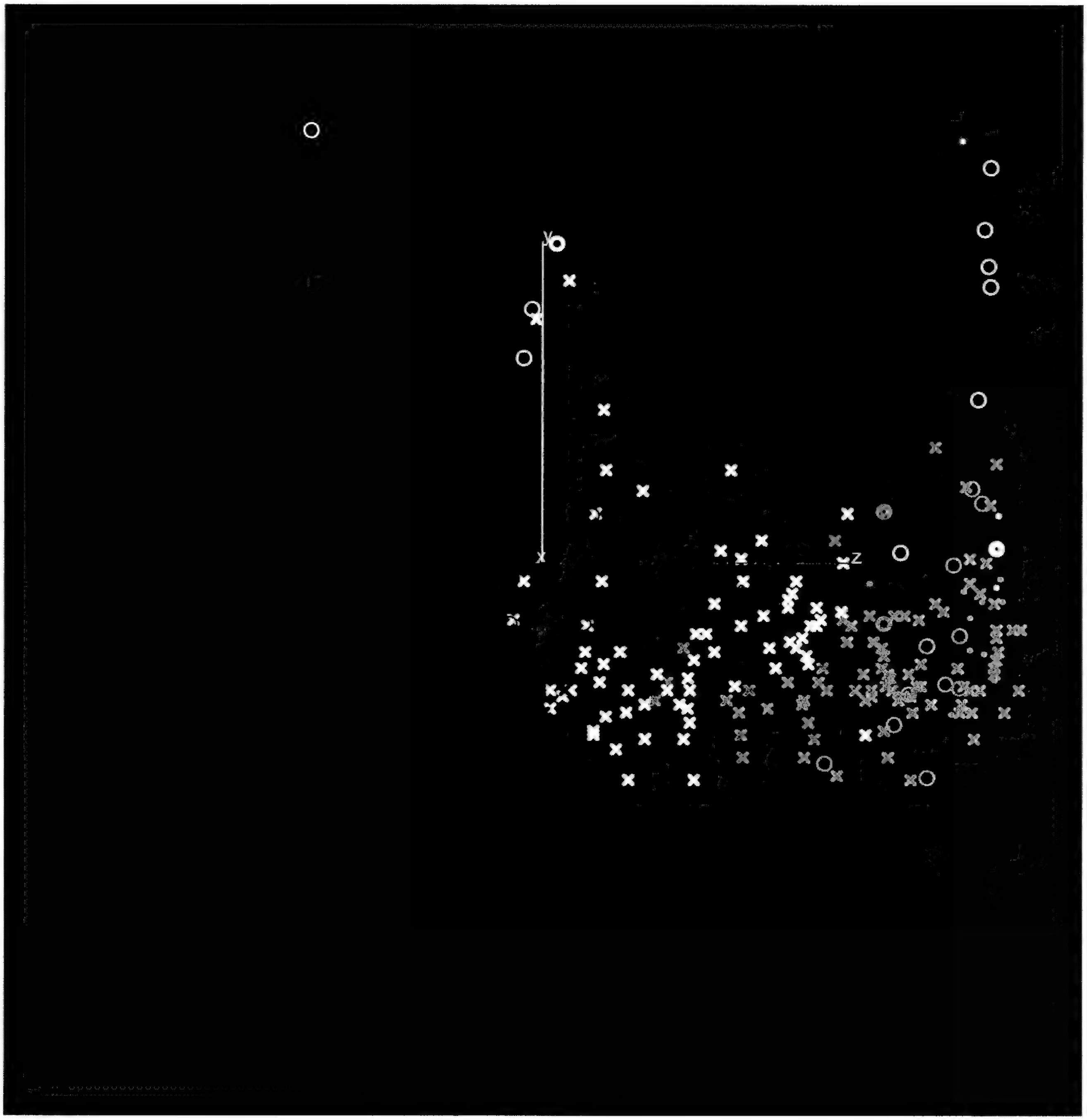


Fig. 3. Graph of Relative Humidity (Z-Axis) 2.3 m AGL and Mean CAB 0.3 m AGL (Y-Axis). Colored symbols for 2.3 & 6.3 m temperature difference (magenta, (+ΛT) or unstable; blue green, (-ΛT) or stable; white, neutral); ); symbols for prevailing wind directions ((x) or WNW (230 to 10° with mean 307°); (0) or ENE (10 to 150° with mean 64°), ( □ ) 150 to 230°) during the summer of 1996 at the Willamette River Valley observation station.

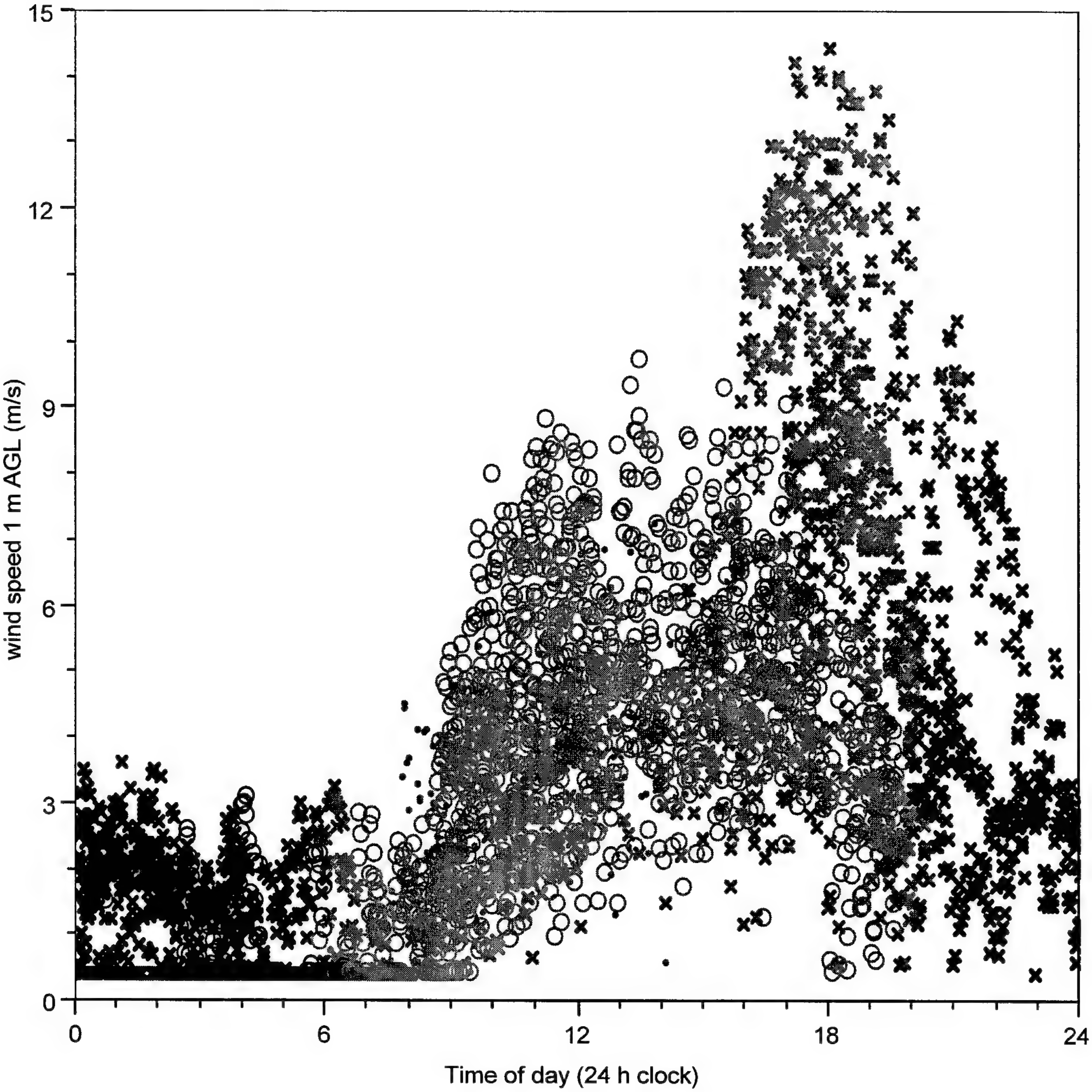


Fig. 4. Wind Speed Versus Time of Day During the Summer of 1996 at the Willamette River Valley Observation Station. Gray is sunlight, black is no sun light and X is WNW, O is ENE wind direction, and is 150 to 230° wind direction.

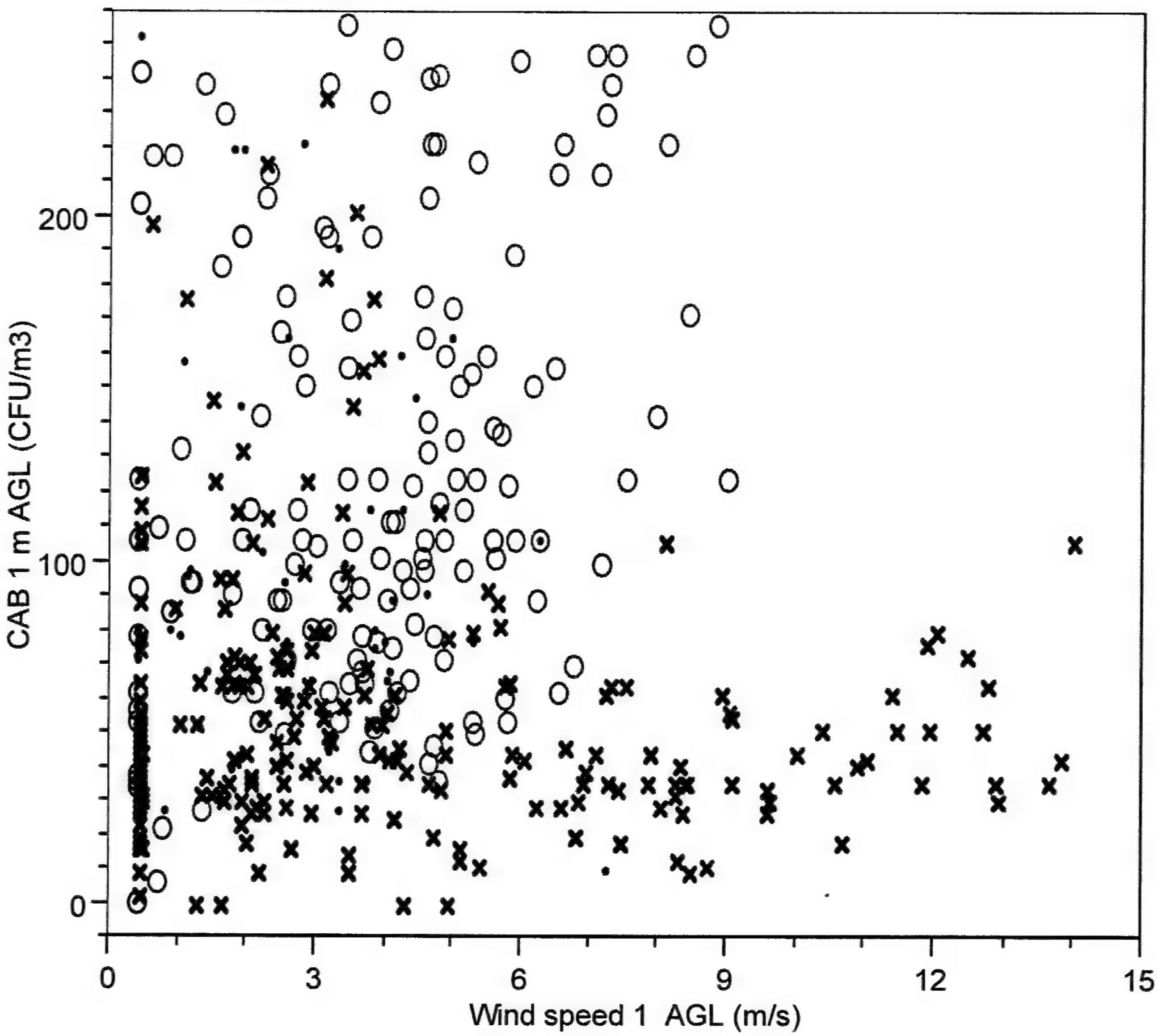


Fig. 5. Graph of Wind Speed Versus CAB Showing Generally Lower CAB Concentrations in Higher Wind Speeds From WNW and Higher Concentrations in Lower Wind Speeds From the ENE. See Figure 4 for symbol definitions.

plants alter their electrostatic charge (e.g., Leach, 1987)? Or is it some other mechanism or a combination of mechanisms? The second question is somewhat related to the first. Is the source of the ambient CAB from local or distant sources? What is the flux, including resuspension, of bacteria from vegetation and soil?

The study of the atmospheric bacteria dispersal dynamics is needed to understand the moment-to-moment variations in the natural atmospheric, or in military terms background, populations of bacteria. These variations may significantly contribute to false reactions in detection instruments. Understanding what environmental conditions contribute to the dynamics will allow adjustment in detection reliability by knowing when detector reactions may or may not be compromised by ambient background bacterial populations.

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